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(54) Title: FLOOR COVERING WITH SENSOR

(57) Abstract: An intelligent floor covering that monitors itself by detecting environmental changes. The floor covering has a wear layer, a backing layer and a sensor typically positioned between the wear layer and the backing layer. The sensor generates a signal responsive to the environmental changes. The floor covering utilizes a controller, having for example, a computer chip to receive and process these signals. The microchip analyzes the signals and produces coded singals that indicate the environmental changes on the floor covering. These coded signals are then transmitted to an external controller, usually a device such as a computer or environmental controller, where the coded signals can be further processed and displayed if needed.

# FLOOR COVERING WITH SENSOR

## Claim of Priority

This application claims benefit of the filing dates of U.S. Provisional Application Serial No. 60/137,544 filed June 4, 1999, the entire contents of which are hereby incorporated by reference.

## Field of the Invention

This invention relates to carpet, carpet tile and other floor coverings, and in particular, to an "intelligent" carpet tile or modular floor covering that utilizes a sensor or sensors to monitor the status of the tile by detecting changes on or in the tile, such as moisture, load, temperature, pressure, humidity, light or other physical changes or conditions.

## Background of the Invention

Typically covering the entire floor of a space, carpet, carpet tile or other flooring covers a significant fraction of all interior surfaces and occupies an extremely important portion of the interior space. Historically, however, carpet, carpet tile and other flooring have been entirely passive, accumulating "information" only in the form of soiling and wear and "reporting" that information only by visual inspection.

Wear surfaces and backing layers of carpet tiles include a variety of materials such as nylon, vinyl and other polymers. Over time, these materials wear from use. An advantage of carpet tiles includes the capability to replace only the worn carpet tiles and not the entire carpeted surface.

However, the wear on carpet tiles may not evenly distribute across the entire wear surface. For example, carpet tiles in hallways experience more wear than their counterparts in the corners of rooms. Replacing the entire carpet results in some discarded carpet tiles that are still useable. Replacing carpet tiles with new ones consumes natural resources and requires capital.

Discarding worn carpet tiles potentially causes environmental problems because man-made materials used to make certain carpet tiles decays slowly. Increasing the quantity of carpet waste may negatively impact the environment. Disposing of used carpet tiles to the satisfaction of environmental concerns may require sophisticated waste processing technology and substantial capital injection. Therefore, prolonging the useful life of carpet tiles results in a reduction in the replacement of carpet tiles, and therefore costs. Further, prolonging the useful life of carpet tiles benefits the environment.

A method for prolonging the useful life of carpet tiles involves proper maintenance of the tiles. Well-maintained carpet tiles last longer. However, excessive carpet maintenance increases maintenance costs, and reduces the effective life of carpet tiles due to unnecessary wear caused by maintenance machinery, crew and chemicals. Ideally, maintenance of carpet tiles occurs only when needed.

Currently, routine maintenance of carpet tiles typically occurs on scheduled intervals or on an as-needed basis. Basing the scheduled maintenance on budget or time does not account for the intrinsic need of the carpet tiles for maintenance. A quantitative basis for determining the wear status of a carpet is not available. Current carpet tiles cannot record wear and "tell" maintenance personnel when routine maintenance should occur.

The degree of wear of a carpet tile is proportional to the traffic on the carpet. Therefore, the status of the carpet tile can be gauged by monitoring that traffic.

Moreover, because traffic depends on location, carpet tiles at some locations, such as doorways, hallways and the like, bear more traffic and are more likely to wear out than carpet tiles at other locations. Interchanging carpet tiles at heavily trafficked locations with lightly trafficked carpet tiles prolongs the overall life of the carpet tiles. Timing the exchange is critical. For instance, once a carpet tile shows visible wear, it may be too late to interchange it with a carpet tile from

another location in good condition; but interchanging them too often is costly, unnecessary, and troublesome.

Thus, a need exists for a modular floor covering that monitors the status of the floor covering by detecting changes on or in the floor covering.

## Summary of the Invention

This invention is an "intelligent" floor covering in the form of carpet, carpet tiles, or flooring of the type disclosed in PCT application No. PCT/US98/21487 published April 22, 1999, which is incorporated herein by this reference, having the capability to monitor changes on the surface of, or within, the carpet tile or other floor covering. Portions, or the entirety, of a floor covered by the carpet, floor covering or tile of this invention thus becomes an "active" or "intelligent" component of the building, able to sense conditions on or near the tile or other floor covering, such as loads, moisture, humidity, temperature, pressure, light and changes in magnetic fields and buildup of static charges.

Sensed information can be used to control other equipment directly and immediately. For instance, the load of the first foot-fall on a tile of this invention at a doorway can turn on room lights, and the last foot-fall of a departing room occupant can turn those lights off. Sensed information can also be accumulated and processed within a tile or an array of tiles, for instance in a microchip, before contemporaneous or delayed transmission elsewhere.

Floor covering of this invention, like conventional carpet tile and the floor covering of PCT application No. PCT/US98/21487 includes multiple components, typically including an upper wear surface, such as a tufted or woven layer and backing structure, typically including intermediate components and a bottom layer such as an ACTIONBAC polypropylene layer. One of the intermediate components or layers may be a sensor or sensor structure. Various conventional components, including a cushioning layer, can be provided between the sensor component or layer and the lower under surface for additional support and insulation.

The intelligent component(s) may be an embedded discrete component such as a load sensor, a strain gauge, a thermocouple, a piezoelectric transducer, a hygrometer, or a moisture sensor or any other type of physical sensor or transducer. Such a transducer or sensor may be coupled directly to separate equipment controlled by the transducer or sensor or to readout equipment. For instance, a light or alarm might be directly controlled through conventional switching circuitry to indicate a load such as a foot-fall on the intelligent tile. Alternatively, readout devices such as gauges, meters or computer displays may be coupled to the transducer or sensor, again through conventional control circuitry, to indicate conditions on or near the intelligent tile, such as temperature, load, pressure, humidity, moisture presence or atmospheric pressure.

In another alternative, the transducer or sensor may be coupled to, or incorporated in, logic, memory or other components also incorporated in the intelligent tile so that sensed data are further processed or accumulated before transmission elsewhere or "collection" by, for instance, periodic "interrogation" of the intelligent tile to retrieve stored data.

In yet another alternative, the sensor may not be separately embedded in the tile but, rather formed as a part of the tile. For instance, piezoelectric material may be incorporated in a tile layer so that pressure exerted on the tile generates a current sensible via conductors attached to that layer. Similarly, material having resistivity or impedance that vary as a function of pressure, temperature, moisture level, proximity (of objects) or other changes in physical condition may be incorporated in a carpet or carpet tile layer, and conductors attached to that layer may be coupled to resistance or impedance measuring circuitry for measuring or monitoring such changes.

In one embodiment, the tile utilizes a microchip to receive and process signals responsive to the load changes. The microchip analyzes the signals and produces coded signals indicating the status of the carpet tile. These coded signals are then transmitted, wirelessly or through cables, to an external receiver, usually a

terminal device such as a computer or visual monitor, for further processing and display.

The external receiver can be any monitoring device. In one embodiment, the external receiver is a computer with a display. The computer saves the coded signal in its memory. An operator can review the current status of a tile, or review historical data on the tile, as an aid in determining if particular work must be performed on the tile. Thus, maintenance of the tile can be performed timely and accurately.

Other applications for this invention include improving security or safety by installing the intelligent tiles with a warning alarm along the edge of a room, stage, podium, or like structure; placing intelligent tiles in a theater, meeting hall or the like as a location indicator; utilizing intelligent tiles in a storage facility for monitoring inventory; and identifying trespassers by strategically placing intelligent tiles on a floor where the intelligent tiles function as a security system.

A simple application of this invention is control of room lighting by detecting a foot-fall at a room doorway. More sophisticated utilization of the invention is possible, however, by utilizing an array of tiles with pressure transducers covering an entire room, or a larger floor covering, such as a "broadloom" carpet with an array of sensors in the floor covering. By monitoring load applications throughout the room, such as those caused by persons walking or standing within the room, it is possible to monitor the entry and exit and presence of people in the room, enabling control circuitry to respond to the entry of the first person and the exit of the last person to leave the room by, for instance, turning room lighting on and off or altering light levels within portions of the room in response to movement within the room. Air pressure on individual tiles can also be monitored. Such occupancy and air flow and temperature data can also be used to control HVAC. Recognizing that each person contributes heat to a room having a normal air temperature, data from an intelligent floor can be used to adjust cooling in an auditorium in response to the influx of a large number of people in anticipation of the heat input from those people. This can facilitate maintenance of

a uniform air temperature, rather than one that fluctuates because increased cooling occurs in response to a measurable rise in air temperature from such an influx of people into the auditorium. Such HVAC control can also be used to adjust heating or cooling levels in discrete portions of an auditorium or other large room if the data from the intelligent floor indicate that occupants are clustered in portions of the auditorium.

Combinations of sensors may be incorporated in a single tile or array of tiles of this invention. For instance, pressure or load sensors can be combined in a tile with temperature sensors and light sensors. Additionally, data from particular sensors or groups of sensors may be used for multiple applications. For example, an array of load, light and temperature sensors in intelligent tiles located in an auditorium or other large room can be used to monitor the entry, presence and exit of occupants, load cycles, and light levels and temperature. That data can be used, among other things, to: (a) control room lighting, including control of light levels within the room in response to movement of occupants within the room and the level of daylight in the room, (b) control HVAC in order to control overall room temperature and temperature of zones within the room, accounting for heat contribution from occupants (c) monitor floor covering wear and soiling, and (d) monitor floor covering maintenance (by, for instance, monitoring vacuuming).

Such an array of intelligent tiles can also engage in interactive processes with room occupants. For instance, a theater patron given an assigned seat ticket enters a theater containing floor covering of this invention. Pressure sensors in the floor note the presence and location of the patron. Remote reading sensors also read the ticket in the patron's possession and identify the seat associated with that ticket. Light emitting elements in tiles forming a path from the patron's location to the seat can then be actuated sequentially, flashing in a progression leading to the seat. This lighted path can correct itself if the patron does not walk directly to the seat, continually displaying a new path leading to that seat until the patron occupies the assigned seat.

An array of intelligent tiles on a floor, which have multiple sensors or different sensors and which are interconnected become a sort of neural network able not only to collect data about conditions on and near the tiles in the room but also to process and manipulate such data for the purposes described above, combinations of purposes described above and other purposes. Thus, a floor containing an array of such intelligent tiles becomes a large data gathering system and a computational and data processing system.

Thus, the objects of this invention include the following:

To provide an intelligent tile for detecting, capturing and monitoring changes on or in the tile.

To provide an intelligent floor for detecting, capturing and monitoring changes on or in the floor or portions of the floor.

To provide an intelligent tile that utilizes a microchip to monitor changes.

To provide an intelligent tile that employs pressure sensors to detect load changes and generate signals responsive to the load changes.

To provide an intelligent tile having moisture monitoring for counting cleaning cycles or other purposes such as liquid spills in a restaurant or health care facility.

To provide an intelligent tile that counts the number of time tiles have been vacuumed.

To provide an intelligent tile that measures temperature or room occupancy as part of HVAC control.

To provide an intelligent tile that employs pressure sensors formed of piezoelectric materials to detect the load changes and generate signals responsive to the load changes.

To provide an intelligent tile that communicates with an external device regarding its status or aspect of its history.

Other objects and advantages will appear from the drawings and specification.

## Brief Description of the Drawings

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate preferred embodiments of this invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 shows a perspective view of tiles of this invention including intelligent tiles, arranged to form a floor covering.

Fig. 2 shows a side sectional view of the intelligent tile of this invention used in Fig. 1.

Fig. 3 shows a three dimensional, sectional view of the intelligent tile without an upper wear surface and having a layer of piezoelectric material as a detecting device.

Fig. 4 shows a three dimensional, sectional view of a first alternative embodiment of the detecting device.

Fig. 5 shows a three dimensional, sectional view of a second alternative embodiment of the detecting device.

Fig. 6 shows a three dimensional, sectional view of a third alternative embodiment of the detecting device.

Fig. 7 shows a block diagram of a microchip coupled to the intelligent tile.

Fig. 8 shows a three dimensional view of an electric connection used in an embodiment of the invention.

Fig. 9 shows a three dimensional view of an alternative embodiment of the electric connection of Fig. 8.

## Detailed Description

Fig. 1 shows a perspective view of tiles of this invention including intelligent tiles, arranged to form a floor covering. Tiles 10 cover a sub-floor or flooring 2, forming a floor covering area 4. Area 4 is a matrix of tiles, extending from one end 12 to the opposite end 14 of area 4. The area 4 can be sized to fit the room dimensions. Tiles 10a to 10i that form a row 8 near a gateway 6 include "intelligent" tiles of this invention. The location of the row having intelligent tiles

can be varied. For instance, instead of having a row of intelligent tiles neighboring gateway 6, it can be located at the center of the room. Furthermore, in some applications, it may be useful to have more than one row of intelligent tiles or an entire area of intelligent tiles.

Fig. 2 shows a side view of the intelligent tile 10. Each intelligent tile 10 in row 8, has an upper wear surface 22 and a lower under surface 30. The upper wear surface 22 makes first contact with a passing object, such as a person 1 and bears the load. The load passes from the upper wear surface 22, through the lower under surface 30 to flooring 2. Several layers of material are positioned between the upper wear surface 22 and the flooring 2. Preferably, the upper wear surface 22 includes a layer of textile material 24 providing an upper surface layer. The lower under surface 30 can be a layer of woven or non-woven or polyester materials such as polyvinyl providing a backing layer 28.

A layer of "intelligent" materials 26 detects changes in the environment and generates signals responsive to the changes. The intelligent layer 26 can be interposed between the upper wear surface 22 and the backing layer 28. An optional substrate layer 27 may be positioned between the intelligent layer 26 and backing layer 28 to provide support or insulation or both to the intelligent layer 26. However, intelligent layer 26 may be positioned anywhere in the multi layer tile.

The layer of "intelligent" materials can take various forms. Fig. 3 shows one embodiment of the intelligent layer 26 encompassing piezoelectric material 42. Piezoelectric materials 42 include piezoelectric crystal, or other materials capable of functioning as a piezoelectric transmitter or generator. In use, when an object makes a contact with upper wear surface 22, the load on upper wear surface 22 changes, pressing down the upper wear surface 22. The load change is passed to intelligent layer 26 of piezoelectric material 42, which generates an EMF or an electric signal in response. The strength of the electric signal is proportional to the load change. A microchip 40 electrically connects to intelligent layer 26. The microchip 40 collects the responsive electric signal and processes the data.

Further, the floor covering can be made such that the floor covering embodies a complete flooring surface of intelligent tiles. In one embodiment, the method provides for the intelligent tile having piezoelectric transducers and functioning as a sensor or chip without embedding the sensor into the carpet.

Fig. 4 shows an alternative embodiment of the intelligent layer 26 as a network of pressure sensors 44. The network can be formed as a two dimensional array with a pressure sensor 44 at each node. Each pressure sensor 44 links to neighboring pressure sensors 44 by conducting wires 45. Pressure sensor 44 responds to the pressure or load change it detects with an electric signal. In this embodiment, pressure sensor 44 include piezoelectric crystals and operates based on the piezoelectric effect. Conducting wires 45 are metal wires, including wires made from copper, aluminum, other metals, or a composite of metals.

In use, when an object makes contact with the upper wear surface 22, changing the load on upper wear surface 22. A responsive EMF or an electric signal is generated if at least one pressure sensor 44 activates by the load change. If several pressure sensors 44 are activated simultaneously, the respective electric signals are summed. In this case, the magnitude of the summed signal can be chosen from the largest magnitude among the signals or the averaged magnitude over the signals. The microchip 40 connects to the network by conducting wires 45. Microchip 40 collects the responsive electric signal for processing.

Fig. 5 shows another alternative embodiment of the intelligent layer 26 including an ensemble of piezoelectric wires 46. Each wire 46 is capable of generating an electric signal responsive to load change. Similarly, the microchip 40 connects to the network by conducting wires 46. Microchip 40 collects the responsive electric signal for processing.

Fig. 6 shows yet another alternative embodiment of the intelligent layer 26 including an arrangement of springs 48. Springs 48, when pressed by the load of an object, produce a tension force proportional to the load change. This tension force transforms into an electrical signal which transports to the microchip 40.

In the embodiments discussed above, each embodiment can include an optional substrate layer, (denoted by numerals 32, 34, 36 and 38 in Figs. 3-6, respectively), providing further support and insulation to the intelligent tile 10.

Fig. 7 shows the microchip 40 having a memory 50, a controller 52 and an interface 54 for cooperating with a user interface. When microchip 40 receives an electrical signal generated by intelligent layer 26 in response to the load change, microchip 40 saves the signal in memory 50 and processes it. Controller 52 connects to and communicates with intelligent layer 26 to receive signals generated by the sensors. Preferably, controller 52 encompasses a microprocessor and a digital signal processor. The pressure sensor(s) 44 and the microchip 40 are reusable when the upper wear surface is replaced.

Memory 50 connects to controller 52 and provides for storing signals or other types of information. Memory 50 may include static RAM, Dynamic RAM, Flash RAM, EEPROM or any type of memory suitable for storing signals and allowing the retrieval of the signals. The size of memory 50 may vary depending on the user's application. Interface 54 connects to controller 52 and contains all necessary input and output devices. For example, interface 54 may contain keypad and switches for programming the microchip 40. Interface 54 can contain other types of input/output devices depending on the signal processing and application. Non-limiting examples include, a signal transmitting device, a battery, an electric connection, switches, or any input or output device which allows or assists communication between microchip 40 and a perspective user directly, or indirectly through an external device.

Controller 52 can be preset to categorize the signals it receives, thus making microchip 40 programmable. Weight projected onto pressure sensors can be converted to an electrical signal based on the piezoelectric effect. Each time an electric signal falls to a pre-selected range, microchip 40 counts that signal as one passage by a person and produces a coded signal accordingly. Similarly, different thresholds can be established to categorize machinery or the like according to their range of weight. Therefore, each time an object passes over the tile and makes a

contact with it, pressure sensors 44 detect the passage and microchip 40 produces a coded signal to characterize that passage.

Memory 50 saves the coded signals in and transmits them to an external receiver (not shown) through an electric connection contained in interface 54. Fig. 8 shows one embodiment of the electric connection as a nonresonant wireless device 56. The nonresonant wireless device 56 has two coils. The first coil 58 relays power to microchip 40. The second coil 60 receives the coded signal from controller 52 and transmits the signal to the external receiver.

Fig. 9 shows an alternative embodiment of the electric connection as a resonant wireless device 62. The resonant wireless device 62 includes at least one coil 64 and one low pass filter 66. The coil 64 relays power to microchip 40. The low pass filter 66 receives and transmits the coded signal to the external receiver. These embodiments of the electric connection serve as non-limiting illustrations and can embody alternative forms, for example, microchip 40 can be powered by a battery. Alternatively, microchip 40 may be powered through a regular electric connection to a wall or surface outlet. Moreover, the coded signals from microchip 40 may be transmitted to the external device directly through a cable or the like.

The external receiver can embody monitoring devices including, for example, a computer with a display. The computer saves the coded signal in its memory. An operator can review the current status of the tile. Alternatively, an operator can review the historic status of the tile on the visual display. The status information can take various forms including a summary of contacts made to the intelligent tile 10. Based on the information, an operation decides what actions should be taken, such as moving or replacing the tiles or performing maintenance activities. Thus, timely and accurate maintenance of the tile can be performed. The computer can be programmed with threshold levels that when the threshold (i.e. number of passes) is met the computer generates a signal, visual or audio or both. In addition, the operator can survey the overall state of the tiles by checking the historical data and take proper responsive measures. For instance, the operator

may interchange the tile having the most passes with the tile having the least passes before wear becomes visible.

Another application for this invention includes, programming the microchip to record maintenance history on the tiles, which is useful where a robot cleaner performs maintenance on the tiles. Since the maintenance provider knows the weight of robot cleaner, the microchip can be programmed to record the number of maintenance activities an intelligent tile receives from the robot cleaner.

Another non-limiting application includes improving safety by installing the intelligent tiles along the edge of a stage, a podium, or the like structure. The intelligent tiles would be equipped with an indicative signal, visual or audio or both. The indicator alarms when at least one of the intelligent tiles detects a load change thereby preventing people from falling or becoming trapped in the structure. Moreover, theaters, meeting halls and the like can utilize the intelligent tile as a location indicator. For example, a person late for movie and trying to locate his or her seat in dark steps on an intelligent tile. Upon stepping on the intelligent tile, at least one pressure sensor detects the load change and the microchip transmits a coded signal in response. The switch turns on when it receives the coded signal from the microchip. When the switch is on, the indicator displays information indicating the location of the tile, and at the same time, provides illumination. After the object moves away from the tile, the switch goes off and so does the indicator. An advantage over traditional foot lighting includes providing an activated light that does not remain on constantly.

Another application involves utilizing the intelligent tile in a storage facility for monitoring inventory. In this application, the floor of the facility becomes a network of the intelligent tiles. Each tile records the load placed on it and provides that data to a control center. The control center performs an analysis of the load for a designated period and generates an accounting of the inventory. This invention allows the control center to get inventory information without performing a physical inventory.

Still another application involves using the intelligent tile to provide a security system. By placing the intelligent tiles at a location where a trespasser may traverse, the intelligent tile detects load changes when the trespasser steps on the intelligent tile. An alarm connected to the intelligent tile triggers and alarms. Unlike traditional security systems based on motion detecting, the intelligent tiles can be programmed so that only object with "unknown" weight can trigger the alarm, thus eliminating false alarms caused by objects such as pets.

Yet another application involves controlling room lighting by detecting a foot-fall at a room doorway. An array of tiles with pressure transducers covers an entire room, or a larger floor covering, such as a "broadloom" carpet with an array of sensors in the floor covering. By monitoring load applications throughout the room it is possible to monitor the entry and exit and presence of people in the room, enabling control circuitry to respond to the entry of the first person and the exit of the last person to leave the room by, for instance, turning room lighting on and off or altering light levels within portions of the room in response to movement within the room. Such data can also be used to control HVAC. This can facilitate maintenance of a uniform air temperature, rather than one that fluctuates because increased cooling occurs in response to a measurable rise in air temperature from such an influx of people into the auditorium. Such HVAC control can also be used to adjust heating or cooling levels in discrete portions of an auditorium or other large room if the data from the intelligent floor indicate that occupants are clustered in portions of the auditorium.

Another application involves combinations of sensors incorporated in a single tile or array of tiles. For instance, pressure or load sensors can be combined in a tile with temperature sensors and light sensors. Additionally, data from particular sensors or groups of sensors may be used for multiple applications, such as to: (a) control room lighting, including control of light levels within the room in response to movement of occupants within the room and the level of daylight in the room, (b) control HVAC in order to control overall room temperature and temperature of zones within the room, accounting for heat contribution from

occupants (c) monitor floor covering wear and soiling, and (d) monitor floor covering maintenance (by, for instance, monitoring vacuuming).

Still another application involves utilizing this invention to electronically vary the appearance of a floor covering. For instance, intelligent carpet including tubes of fiber controlled by a switch that changes upon demand is within scope of this invention. Alternatively, the intelligent floor covering emits light or diffracts light thereby changing the appearance of the floor covering.

The forgoing description of the preferred embodiments of the invention has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in light of the above teaching.

For example, this invention has been described with reference to use square or rectangular tiles to cover a floor. This invention, however, may be practiced by using tiles with other shapes, such as circular, diamond, oval or other kinds of geometrical configuration. Furthermore, intelligent tiles may be arranged in diagonal, a circle, or the like over a floor.

Additionally, each tile can include multiple sensors, and the size of each "tile" can be varied. Indeed, "broadloom" floor covering can be produced with multiple sensors so that an entire floor may be covered with one, or a small number, of pieces of floor covering of this invention.

While certain embodiments of this invention have been described above, these descriptions are given for purposes of illustration and explanation. Variations, changes, modifications and departures from the systems and methods disclosed above may be adopted without departure from the spirit and scope of this invention.

What is claimed is:

1. A carpet tile comprising:
   a) a wear layer;
   b) a backing layer coupled to the wear layer; and
   c) a sensor for generating signals responsive to environmental changes coupled to at least one of the wear layer or the backing layer.

2. The carpet tile of claim 1, wherein the sensor is mounted between the wear layer and the backing layer.

3. The carpet tile of claim 2, further comprising a substrate layer mounted between the backing layer and the sensor.

4. The carpet tile of claim 3, further comprising a first controller coupled to the sensor for receiving and processing signals generated by the sensor.

5. The carpet tile of claim 4, further comprising at least one memory module connected to the first controller.

6. The carpet tile of claim 5, further comprising an interface for coupling the first controller to an external controller.

7. The carpet tile of claim 6, wherein the sensor comprises a piezoelectric device.

8. The carpet tile of claim 6, wherein the interface comprises a cable.

9. The carpet tile of claim 8, wherein the external controller comprises a battery for powering the sensor and first controller.

10. The carpet tile of claim 6, wherein the interface comprises a wireless device.

11. The carpet tile of claim 10, wherein the wireless device comprises:
    a) a first coil connected to the first controller for transmitting power to the first controller; and
    b) a second coil connected to the first controller for receiving and transmitting signals to and from the external controller.

12. The carpet tile of claim 10, wherein the wireless device comprises:
    a) a coil connected to the first controller for transmitting power to the first controller; and
    b) a low pass filter connected to the first controller for receiving and transmitting signals to and from the external controller.

13. The carpet tile of claim 1, wherein the wear layer comprises textile material.

14. The carpet tile of claim 1, wherein the backing layer comprises polyvinyl chloride material.

15. The carpet tile of claim 1, further comprising a plurality of sensors forming a two dimensional array.

16. The carpet tile of claim 15, further comprising a plurality of wires connecting the plurality of sensors.

17. The carpet tile of claim 6, wherein the external controller comprises an environmental controller for controlling an apparatus for changing the environmental conditions of a room containing the tile.

18. The carpet tile of claim 17, wherein the apparatus for changing the environmental conditions comprises an HVAC system.

19. The carpet tile of claim 6, wherein the first controller further comprises a computer chip.

20. A floor covering comprising:
   a) a wear layer;
   b) a backing layer; and
   c) sensors for generating signals responsive to environmental changes coupled to at least one of the wear layer or the backing layer.

21. The floor covering of claim 20, wherein the sensors are mounted between the wear layer and the backing layer.

22. The floor covering of claim 21, wherein the wear layer comprises a textile material.

23. The floor covering of claim 21, wherein the backing layer comprises a polyvinyl chloride material.

24. The floor covering of claim 21, further comprising a substrate layer positioned between the backing layer and the sensors.

25. The floor covering of claim 21, further comprising a first controller coupled to the sensors for receiving and processing signals generated by the sensors.

26. The floor covering of claim 25, further comprising at least one memory module for storing the signals received from the sensors coupled to the first controller.

27. The floor covering of claim 26, further comprising an interface for coupling the first controller to an external controller.

28. The floor covering of claim 27, wherein the interface further comprises a wireless device comprising:

a) a coil connected to the first controller for transmitting power to the first controller; and

b) a low pass filter connected to the first controller for receiving and transmitting signals to and from the external controller.

29. The floor covering of claim 27, wherein the interface comprises a wireless device comprising:

a) a first coil connected to the first controller for transmitting power to the first controller; and

b) a second coil connected to the first controller for receiving and transmitting signals to and from the external controller.

30. The floor covering of claim 29, wherein the sensors further comprise piezoelectric material.

31. The floor covering of claim 30, wherein the piezoelectric material further comprises piezocrystals.

32. The floor covering of claim 30, wherein the sensors form a two dimensional array.

33. The floor covering of claim 32, further comprising a plurality of wires for connecting the sensors.

34. The floor covering of claim 27, wherein the external controller comprises an environmental controller for controlling an apparatus for changing the environmental conditions of a room containing the tile.

35. The floor covering of claim 34, wherein the apparatus for changing the environmental conditions comprises an HVAC system.

36. The floor covering of claim 27, wherein the external controller further comprises a computer.

37. The floor covering of claim 27, wherein the first controller further comprises a computer chip.

38. A multi-layer floor covering comprising:

a) a wear layer;

b) a substrate layer coupled to the wear layer;

c) a backing layer coupled to the substrate layer;

d) a sensor for generating signals responsive to environmental changes coupled to at least one of the wear layer, substrate layer or backing layer;

e) a first controller connected to the sensor, for receiving and processing a plurality of signals generated by the sensor; and

f) an interface coupled to the first controller for transmitting power to the first controller and transmitting the signals from the first controller to an external controller.

39. The multi-layer floor covering of claim 38, wherein the sensor further comprise piezoelectric material.

40. The multi-layer floor covering of claim 38, wherein the interface further comprises a wireless device.

41. The multi-layer floor covering of claim 40, wherein the wireless device comprises:

a) a first coil connected to the first controller for relaying power to the first controller; and

b) a second coil connected to the first controller for receiving and transmitting signals to and from the external controller.

42. The multi-layer floor covering of claim 40, wherein the wireless device comprises:

a) a coil connected to the first controller for transmitting power to the first controller; and

b) a low pass filter connected to the first controller for receiving and transmitting signals to and from the external controller.

43. The multi-layer floor covering of 38, further comprising a battery for powering the first controller.

44. The multi-layer floor covering of claim 38, wherein the wear layer comprises textile material.

45. The multi-layer floor covering of claim 38, wherein the backing layer comprises polyvinyl chloride material.

46. The multi-layer floor covering of claim 38, wherein the first controller further comprises a computer chip.

47. The multi-layer floor covering of claim 38, further comprising a plurality of sensors.

48. The multi-layer floor covering of claim 47, further comprising a plurality of controllers.

49. The multi-layer floor covering of claim 38, wherein the sensor generates a load signal indicative of the load pressure on the wear layer the load signal being received by the first controller for monitoring the load cycles on the wear layer.

50. The multi-layer floor covering of claim 38, wherein the sensor generates a signal indicative of the level of moisture in any one of the wear layer, backing layer or substrate layer the signal being received by the first controller for monitoring the presence of moisture.

51. A method for monitoring the status of a floor covering, comprising the steps of:
   a) generating a signal responsive to environmental changes experienced by a sensor coupled to the floor covering;
   b) transmitting the signal to an external controller.

52. The method of claim 51, further comprising adjusting the environment responsive to the signal received by the external controller.

53. The method of claim 51, further comprising determining the environmental change by reference to the signal strength.

54. A method for monitoring floor covering wear, comprising:

a) sensing each application of pressure on the floor covering with a sensor in the floor covering; and

b) counting the number of pressure applications.

55. The method of monitoring floor covering wear of claim 54, further comprising:

c) sensing each application of moisture on the floor covering; and

d) counting the number of moisture applications.

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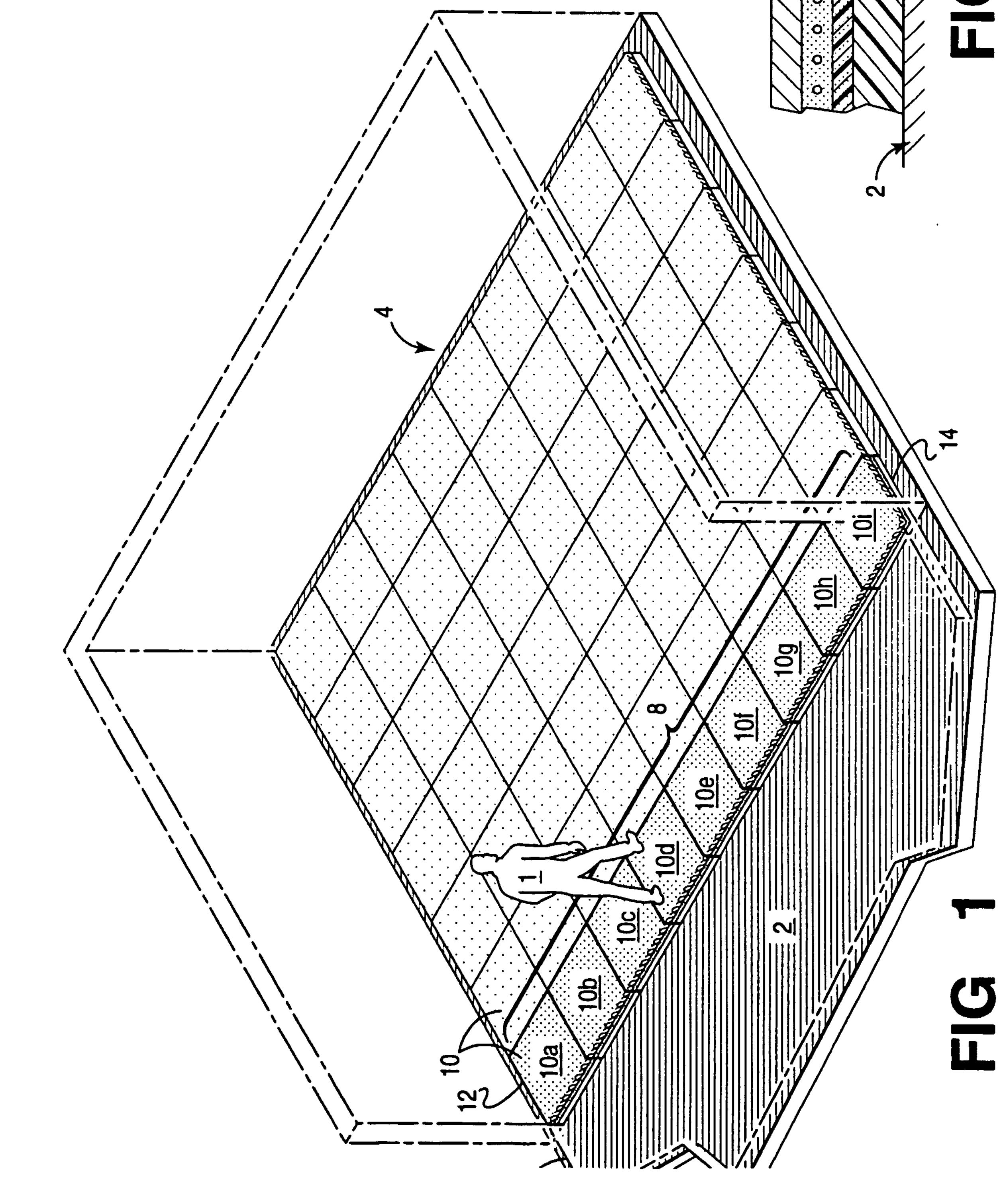

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FIG 1

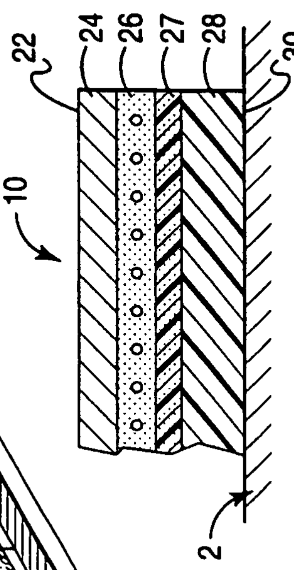

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FIG 2

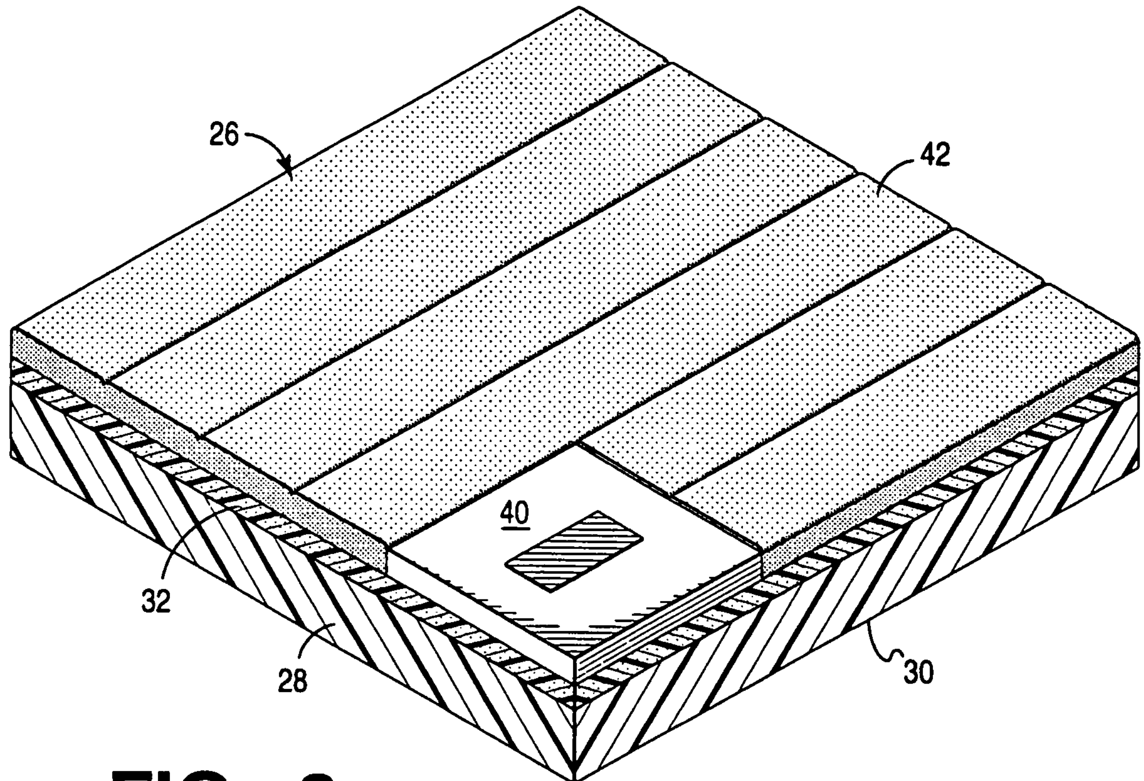
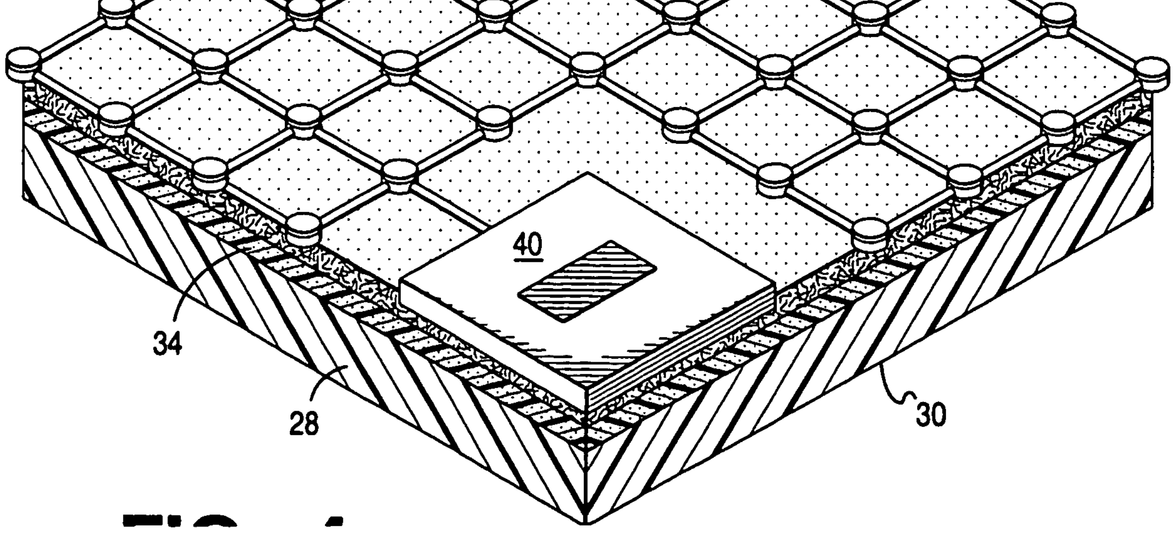



FIG 3



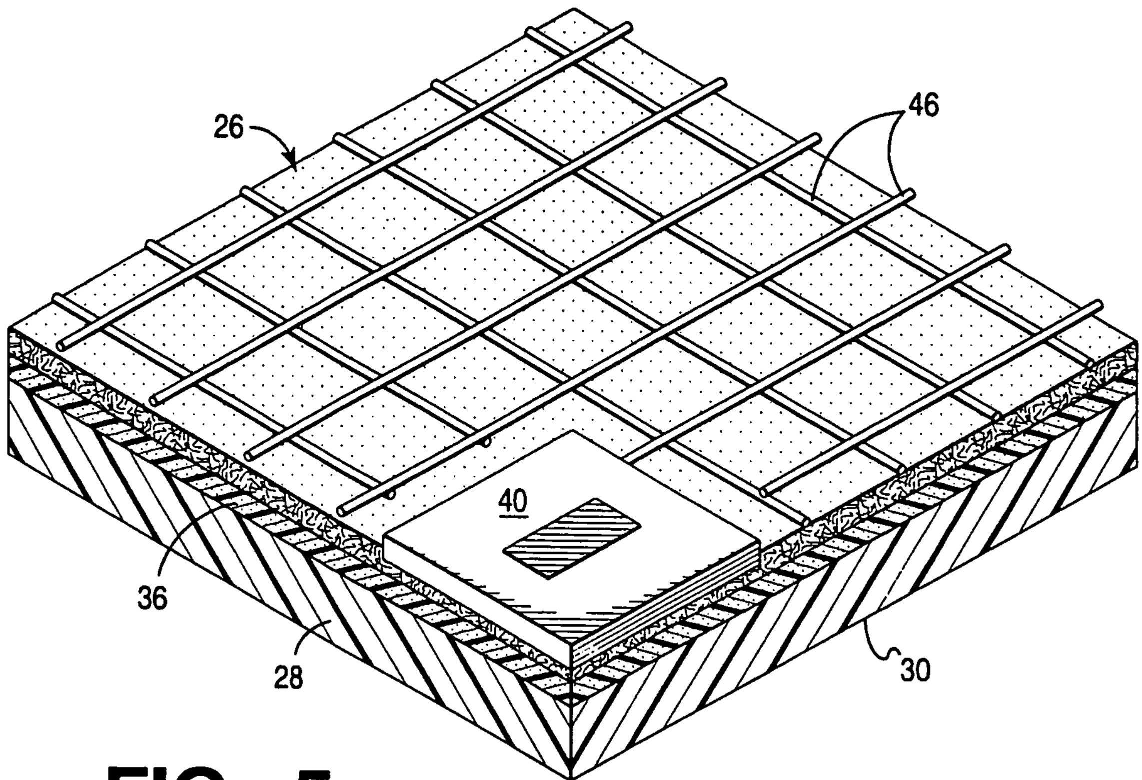
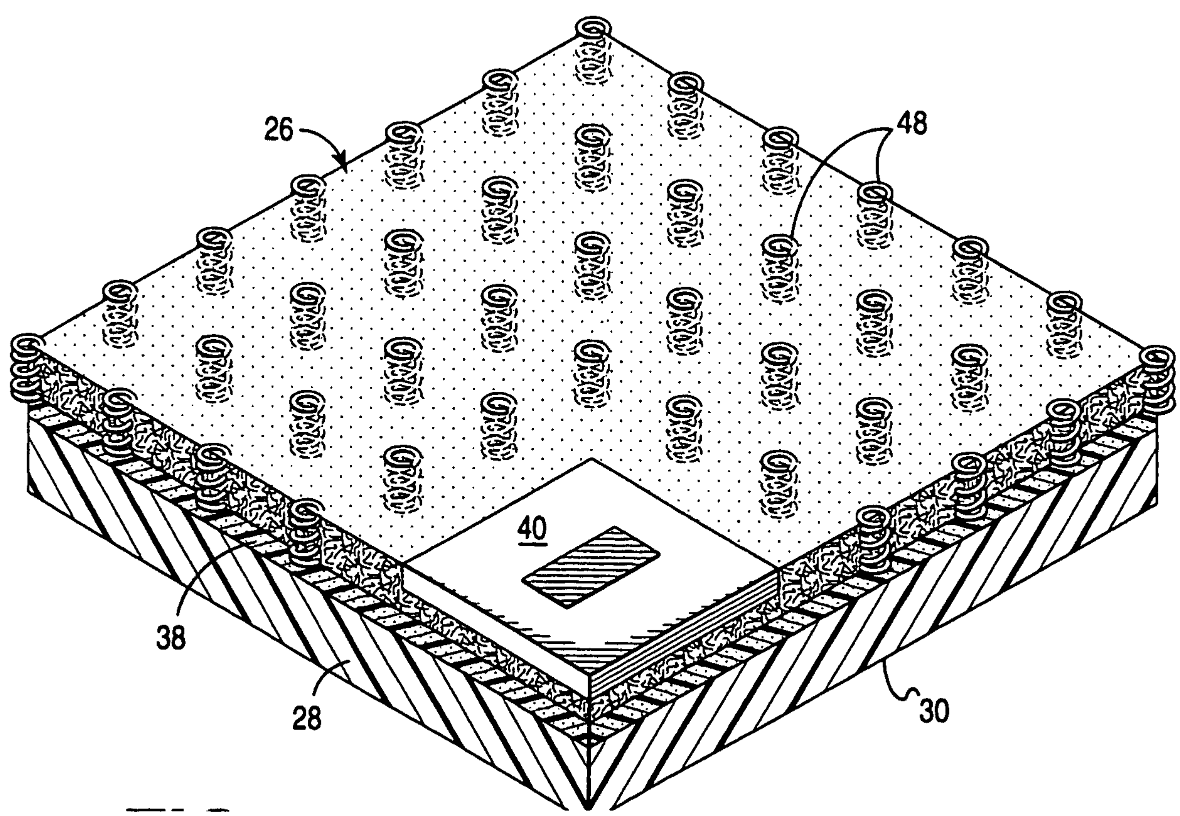



FIG 5



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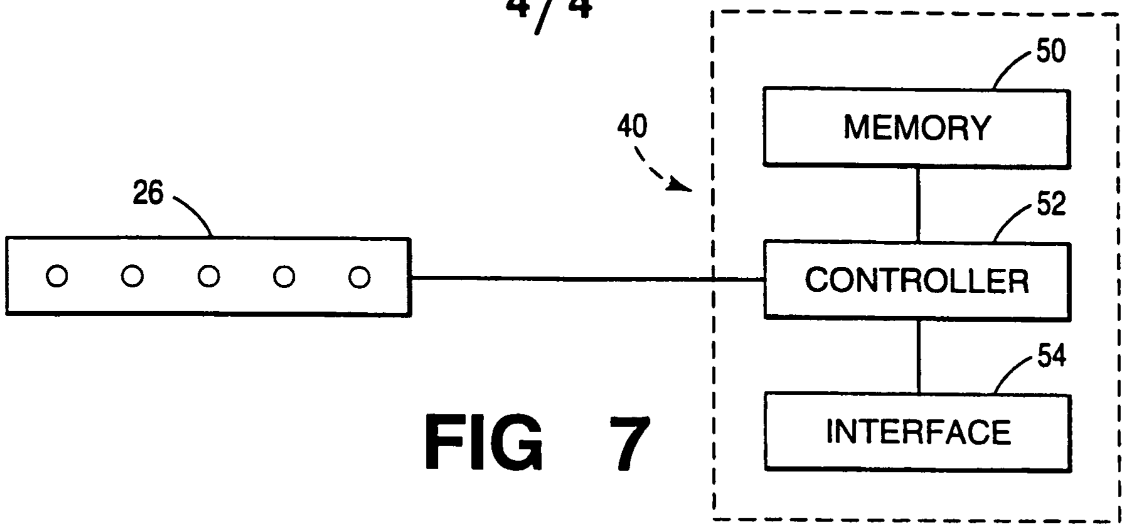


FIG 7

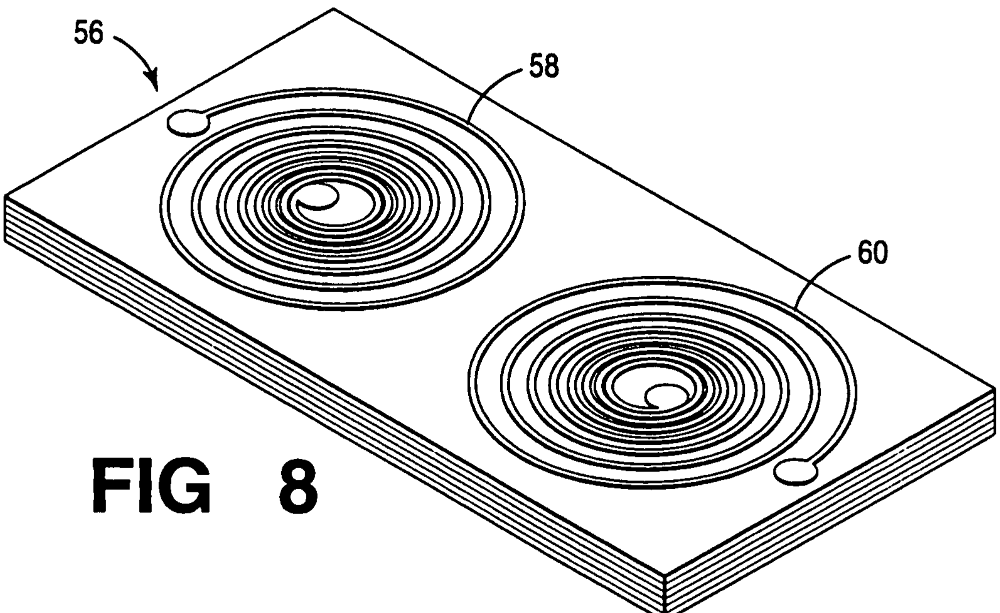


FIG 8

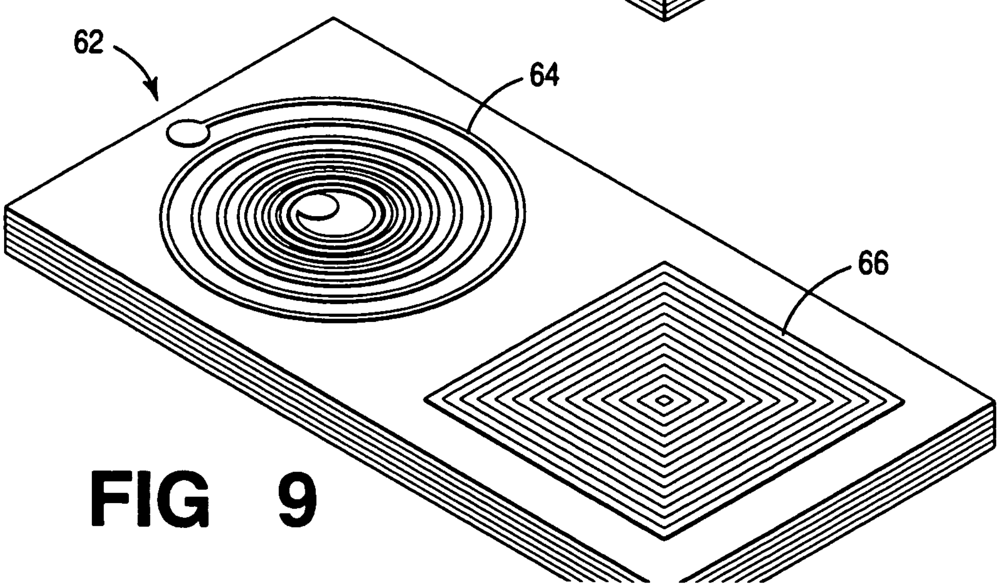


FIG 9

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/15288

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 D06N7/00 E04F15/02 A47G27/02 G01L1/20 G01L5/22
G01G19/44

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01L G01G D06N E04F A47G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 21 September 2000 | 04/10/2000 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016 | Pamies Olle, S |

| International Application No |
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